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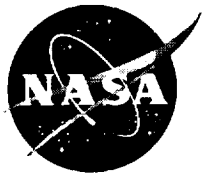

Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and David E. Knapp, Editors

Volume 24

BOREAS HYD-3 Subcanopy Incoming Solar Radiation Measurements

J.P. Hardy and R.E. Davis

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2000

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BOREAS HYD-3 Subcanopy Incoming Solar Radiation Measurements

Janet P. Hardy and Robert E. Davis
U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2000

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BOREAS HYD-3 Subcanopy Incoming Solar Radiation Measurements

Janet P. Hardy, Robert E. Davis

Summary

The BOREAS HYD-3 team collected several data sets related to the hydrology of forested areas. This data set contains solar radiation measurements from several pyranometers (solar radiometers) placed on the snow surface in jack pine (1994) and black spruce and aspen forests (1996) in the BOREAS SSA. An array of radiometers was used to collect data for 3-4 consecutive days in each forest type to study the hypothesis that energy transfer and snow water equivalent would vary spatially as a function of canopy closure. The quality of the data is good, because the days were generally clear and the radiometers were checked daily to remove anything that landed on the radiometers. The data are available in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS HYD-03 Subcanopy Incoming Solar Radiation Measurements

1.2 Data Set Introduction

This data set contains solar radiation measurements from several pyranometers (solar radiometers) placed on the snow surface in jack pine (1994) and black spruce and aspen forests (1996) in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA). In each forest, data were collected for 3 to 4 days.

1.3 Objective/Purpose

This study was undertaken to predict spatial distributions of energy transfer and snow properties important to the hydrology, remote sensing signatures, transmissivity of gases through the snow and their relation to forests in boreal ecosystems. This data set provides a measure of the variability of incoming solar radiation on the snow surface in the various forests. These data will aid in validating a radiative transfer model that predicts the radiation environment beneath a discontinuous forest canopy. The model output will be used to assist in predicting the timing of snow melt in the forest.

1.4 Summary of Parameters

Parameters measured with respect to this documentation are subcanopy incoming solar radiation.

1.5 Discussion

This study was conducted under the hypothesis that energy transfer and snow water equivalent would vary spatially as a function of canopy closure. Net solar radiation has been long known as the primary driving force in snow melt models, yet this parameter is difficult to quantify at the forest floor because of the high spatial variability in radiation transmission through the discontinuous canopy. For this reason, an attempt was made to quantify that variability by operating several (9 in 1994 and 10 in 1996) pyranometers. These pyranometers were run over 3 days of clear sky conditions in 1994 and 4 days in 1996.

The quality of the data is good, because the days were generally clear and the radiometers were checked daily (except in the SSA Old Aspen (OA) in 1996). Any snow that landed on the radiometers was brushed clear, and data for the period were deleted.

1.6 Related Data Sets

BOREAS TF-02 SSA-OA Tower Flux Data
BOREAS TF-01 SSA-OA Tower Flux Data
BOREAS TF-05 SSA-OJP Tower Flux Data
BOREAS TF-09 SSA-OBS Tower Flux Data
BOREAS HYD-03 Subcanopy Meteorological Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Robert E. Davis
Research Physical Scientist
U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)

2.2 Title of Investigation

Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems

2.3 Contact Information

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Greenbelt, MD 20771
(301) 286-1424
David.Knapp@gsfc.nasa.gov

3. Theory of Measurements

In 1994, nine random measurements of incoming solar radiation were made at the snow surface at the SSA-Old Jack Pine (OJP) site to assess the variability in radiation caused by the forest structure. The pyranometers were randomly placed; some measurements were made directly adjacent to tree stems, some in small canopy gaps. These measurements took place over a period of 3 days, and each day, the pyranometers were randomly relocated.

In 1996, 10 random measurements of incoming solar radiation were made at the snow surface at SSA-Old Black Spruce (OBS) and SSA-OA to assess the variability in radiation caused by the forest structure. The pyranometers were randomly placed; some measurements were made directly adjacent to tree stems, some in small canopy gaps. These measurements took place over a period of 4 days, and each day the pyranometers were randomly relocated, except in SSA-OA.

4. Equipment

4.1 Sensor/Instrument Description

Eppley Precision Spectral Pyranometer, measuring wavelengths between approximately 285 and 2,800 nm. This instrument is believed to be the most accurate radiometer produced commercially for the measurement of sun and sky radiation. The pyranometer comprises a circular multijunction thermopile that is temperature compensated to operate effectively at temperatures of -50 °C.

4.1.1 Collection Environment

In all cases, data were collected during the winter, most often during a clear sky period with the lowest air temperatures above the operating threshold of -50 °C. During the 1996 measurement in SSA-OBS, light snowfall landed on the radiometers. The radiometers were brushed clear of snow, and data collected while the radiometers were snow covered were deleted.

4.1.2 Source/Platform

Ground.

4.1.3 Source/Platform Mission Objectives

The mission objective was to measure the variability of incoming solar radiation on the snow surface in SSA-OJP (1994) and SSA-OBS and SSA-OA (1996).

4.1.4 Key Variables

- Total (direct and diffuse) solar radiation beneath the forest canopy.
- Horizontal wind speed at 2 meters above ground beneath the forest canopy.
- Wind speed magnitude vector at 2 meters above ground beneath the forest canopy.
- Wind direction at 2 meters above ground beneath the forest canopy.
- Standard deviation of wind direction.
- Thermal radiation down.
- Canopy temperature.
- Trunk temperature.
- Air temperature at 2 meters above ground.
- Snow surface temperature.

4.1.5 Principles of Operation

The pyranometer outputs a voltage proportional to the incoming radiation; the signal is monitored and data are processed on a Campbell Scientific data logger (CR10). In 1994, measurements were made once every minute and averaged to give a 10-minute output. In 1996, measurements were made every 10 seconds and averaged to give 1-minute output.

4.1.6 Sensor/Instrument Measurement Geometry

Sensors were located on the snow surface using either a foam block (1994) or the radiometer case (1996) for support on the snow surface. Sensors were leveled daily using the bubble level mounted on the radiometer base.

4.1.7 Manufacturer of Sensor/Instrument

Eppley Laboratory, Inc.
12 Sheffield Ave.
Newport, RI 02840
(401) 847-1020

4.2 Calibration

All pyranometers were new in 1994 and were therefore factory calibrated, with reference to Eppley primary standards, just prior to deployment in the field in 1994.

4.2.1 Specifications

Pyranometers

Sensitivity: 9 microvolts per Watt per square meter.
Receiver: circular 1 cm^2 in area.
Linearity: +/- 0.5% from 0 to 2,800 Watts per square meter.
Cosine: +/- 1% from normalization 0-70° zenith angle +/- 3% from normalization 70-80° zenith angle.

4.2.1.1 Tolerance

See Section 4.2.1, Specifications.

4.2.2 Frequency of Calibration

The manufacturer of the pyranometers recommends calibration after a cumulative use of 2 years. These radiometers were new at the beginning of the Focused Field Campaign-Winter (FFC-W) 1994 and therefore are well within calibration. Because they have been used for only ~20 days per year and stored in their dark case when not in use, the calibration should be valid for several years at the current rate of usage.

4.2.3 Other Calibration Information

Available from the manufacturer.

5. Data Acquisition Methods

Each pyranometer was placed on a styrofoam block (1994) or its carrying case (1996) and randomly set on the snow surface. Because of the random placement, some pyranometers were in forest gaps and others were adjacent to tree stems. Data were recorded on a Campbell Scientific data logger. In 1994, the data logger was programmed to measure incoming solar radiation every minute and output 10-minute averages. In 1996, the data logger was programmed to measure incoming solar radiation every 10 seconds and output 1-minute averages.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

1994 Field Campaign

Radiometers were randomly relocated at the following times:

- 08-Feb-1994 between 1700 and 1730 Greenwich Mean Time (GMT).
- 09-Feb-1994 between 1930 and 2000 GMT.
- 10-Feb-1994 radiometers removed around 1800 GMT.

1996 Field Campaign

Radiometers were randomly relocated at the following times:

- 28-Feb-1996 between 2230 and 2245 GMT.
- 29-Feb-1996 between 2230 and 2242 GMT.
- 01-Mar-1996 between 2229 and 2246 GMT.
- 02-Mar-1996 between 2230 and 2239 GMT.
- 01-Mar-1996 at 1802 GMT: the radiometers were cleared of a thin dusting of snow (1802 begins good data).
- 03-Mar-1996 at 1730-1736 GMT: the radiometers were cleared of a thin snow cover.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

1994: SSA-OJP (within 50 meters of tower).
1996: SSA-OBS (within 50 meters of tower).
1996: SSA-OA (within 50 meters of tower).

Tower locations

Tower	Longitude	Latitude
SSA-OJP	104.69203W	53.91634N
SSA-OBS	105.11779W	53.98718N
SSA-OA	106.19779W	53.6289N

7.1.2 Spatial Coverage Map
None given.

7.1.3 Spatial Resolution
The radiometers covered an area approximately 10 m x 10 m.

7.1.4 Projection
All latitude/longitude locations are given in the North American Datum of 1983 (NAD83).

7.1.5 Grid Description
None.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
FFC-W 1994: 06-Feb-1994 - 10-Feb-1994
FFC-W 1996: 28-Feb-1996 - 08-Mar-1996

7.2.2 Temporal Coverage Map
SSA-OJP: 06-Feb-1994 - 10-Feb-1994
SSA-OBS: 28-Feb-1996 - 03-Mar-1996
SSA-OA: 04-Mar-1996 - 08-Mar-1996

7.2.3 Temporal Resolution
1994: 10-minute averages
1996: 1-minute averages

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameters contained in the data files on the CD-ROM are:

```
          Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
DOWN_SHORTWAVE_RAD_1
DOWN_SHORTWAVE_RAD_2
DOWN_SHORTWAVE_RAD_3
DOWN_SHORTWAVE_RAD_4
DOWN_SHORTWAVE_RAD_5
DOWN_SHORTWAVE_RAD_6
DOWN_SHORTWAVE_RAD_7
DOWN_SHORTWAVE_RAD_8
DOWN_SHORTWAVE_RAD_9
DOWN_SHORTWAVE_RAD_10
POSITION
CRTFCN_CODE
REVISION_DATE
```

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
DOWN_SHORTWAVE_RAD_1	The sub-canopy radiation at radiometer #1.
DOWN_SHORTWAVE_RAD_2	The sub-canopy radiation at radiometer #2.
DOWN_SHORTWAVE_RAD_3	The sub-canopy radiation at radiometer #3.
DOWN_SHORTWAVE_RAD_4	The sub-canopy radiation at radiometer #4.
DOWN_SHORTWAVE_RAD_5	The sub-canopy radiation at radiometer #5.
DOWN_SHORTWAVE_RAD_6	The sub-canopy radiation at radiometer #6.
DOWN_SHORTWAVE_RAD_7	The sub-canopy radiation at radiometer #7.
DOWN_SHORTWAVE_RAD_8	The sub-canopy radiation at radiometer #8.
DOWN_SHORTWAVE_RAD_9	The sub-canopy radiation at radiometer #9.
DOWN_SHORTWAVE_RAD_10	The sub-canopy radiation at radiometer #10.
POSITION	The arrangement of the radiometers during a particular period of time.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
DOWN_SHORTWAVE_RAD_1	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_2	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_3	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_4	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_5	[Watts][meter^-2]

DOWN_SHORTWAVE_RAD_6	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_7	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_8	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_9	[Watts][meter^-2]
DOWN_SHORTWAVE_RAD_10	[Watts][meter^-2]
POSITION	[unitless]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Supplied by Investigator]
TIME_OBS	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_1	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_2	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_3	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_4	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_5	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_6	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_7	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_8	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_9	[Supplied by Investigator]
DOWN_SHORTWAVE_RAD_10	[Supplied by Investigator]
POSITION	[Supplied by Investigator]
CRTFCN_CODE	[Assigned by BORIS]
REVISION_DATE	[Assigned by BORIS]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-90A-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	HYD03-SCR01	HYD03-SCR01	None	None	None	None
DATE_OBS	06-FEB-94	08-MAR-96	None	None	None	None
TIME_OBS	0	2359	None	None	None	None
DOWN_SHORTWAVE_RAD_1	-4.726	625.3	-999	None	None	None
DOWN_SHORTWAVE_RAD_2	-4.524	544.2	-999	None	None	None
DOWN_SHORTWAVE_RAD_3	-5.118	482.5	-999	None	None	None
DOWN_SHORTWAVE_RAD_4	-6.792	522.2	-999	None	None	None
DOWN_SHORTWAVE_RAD_5	-3.638	568	-999	None	None	None
DOWN_SHORTWAVE_RAD_6	-5.053	577.3	-999	None	None	None
DOWN_SHORTWAVE_RAD_7	-5.711	646.8	-999	None	None	None
DOWN_SHORTWAVE_RAD_8	-5.7	560.3	-999	None	None	None
DOWN_SHORTWAVE_RAD_9	-6.698	592.7	-999	None	None	None
DOWN_SHORTWAVE_RAD_10	-6.16	611.5	-999	None	None	Blank
POSITION	1	9	None	None	None	None

```
CRTFCN_CODE          CPI            CPI            None    None    None    None
REVISION_DATE        25-JUN-97      25-JUN-97      None    None    None    None

--------------------------------------------------------------------------------
Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value  -- The value that indicates missing data. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the attempt was unsuccessful.
Unrel Data Value   -- The value that indicates unreliable data.  This is used
                      to indicate an attempt was made to determine the
                      parameter value, but the value was deemed to be
                      unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits.  This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
                      determine the parameter value.  This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
--------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following are wrapped versions of data records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,DOWN_SHORTWAVE_RAD_1,DOWN_SHORTWAVE_RAD_2,
DOWN_SOLAR_RAD_3,DOWN_SHORTWAVE_RAD_4,DOWN_SHORTWAVE_RAD_5,DOWN_SHORTWAVE_RAD_6,
DOWN_SHORTWAVE_RAD_7,DOWN_SHORTWAVE_RAD_8,DOWN_SHORTWAVE_RAD_9,
DOWN_SHORTWAVE_RAD_10,POSITION,CRTFCN_CODE,REVISION_DATE
'SSA-OBS-FLXTR','HYD03-SCR01',28-FEB-96,100,-4.726,-4.524,-5.117,-6.792,-3.638,
-5.053,-5.711,-5.7,-6.698,-6.16,4,'CPI',25-JUN-97
'SSA-OBS-FLXTR','HYD03-SCR01',28-FEB-96,101,-4.666,-4.405,-5.118,-6.636,-3.597,
-4.892,-5.691,-5.643,-6.586,-6.076,4,'CPI',25-JUN-97
```

8. Data Organization

8.1 Data Granularity

The smallest unit of obtainable data is the data collected at a given site on a single day.

8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae
Not applicable.

9.1.1 Derivation Techniques and Algorithms
Not applicable.

9.2 Data Processing Sequence
Not applicable.

9.2.1 Processing Steps
Not applicable.

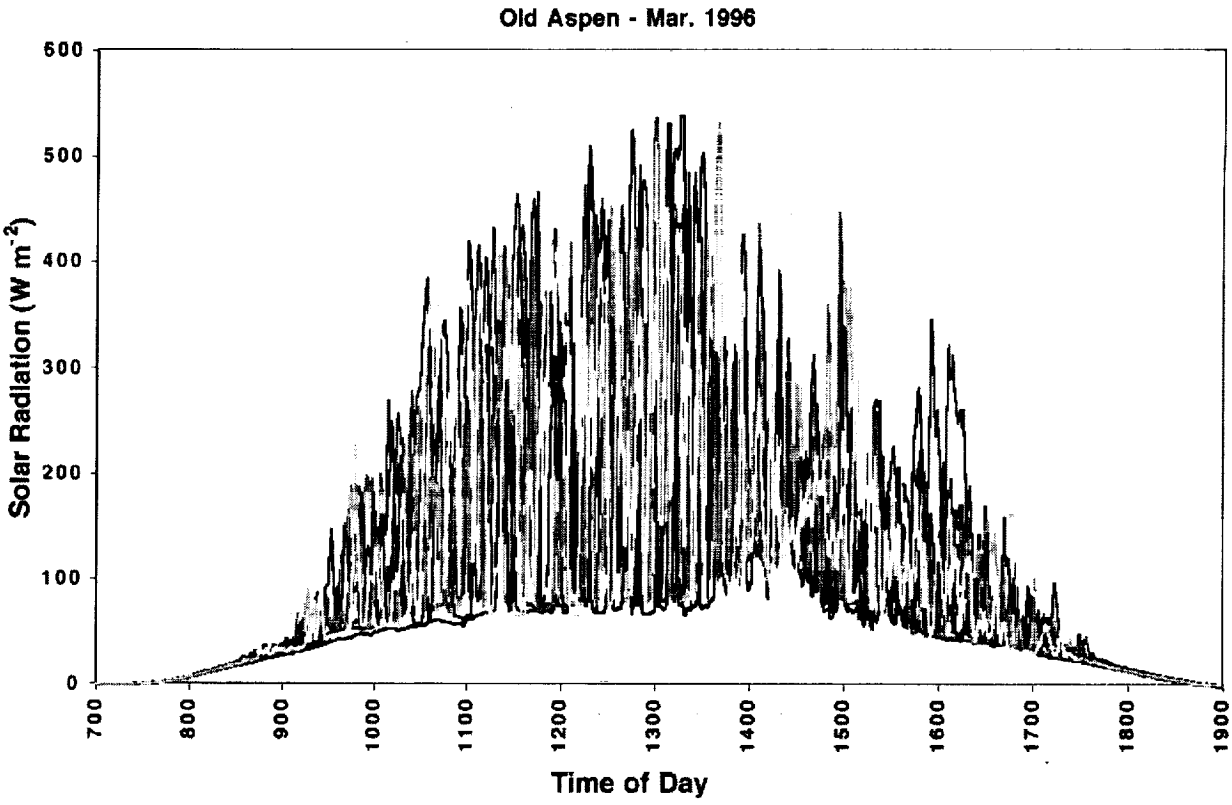
9.2.2 Processing Changes
Not applicable.

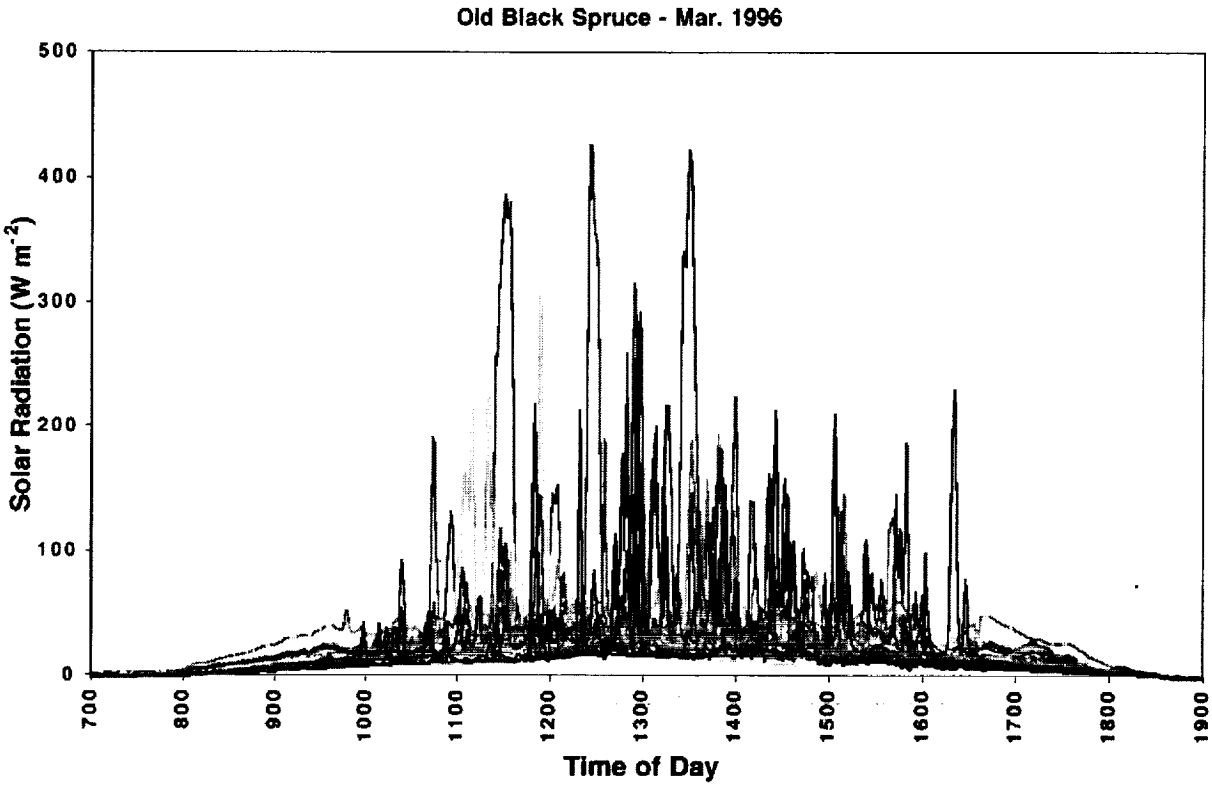
9.3 Calculations

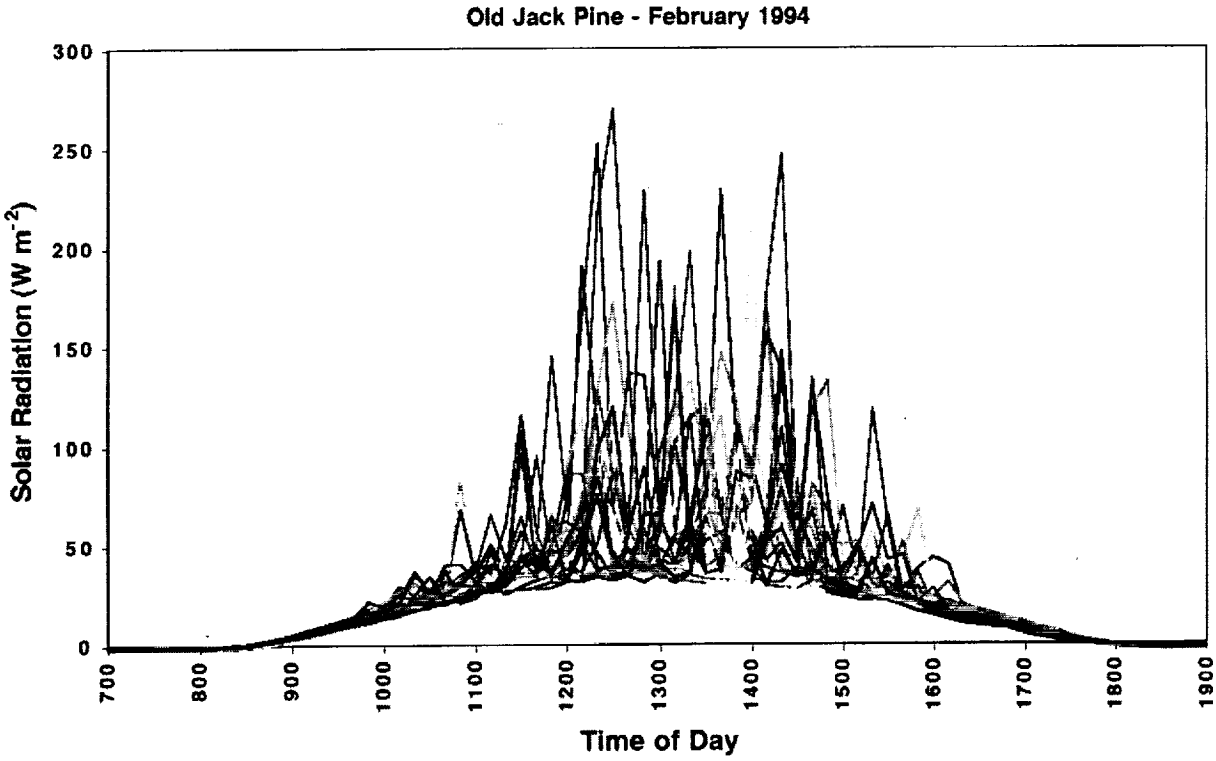
9.3.1 Special Corrections/Adjustments
Not applicable.

9.3.2 Calculated Variables
Not applicable.

9.4 Graphs and Plots
Three plots are included in this documentation showing the variation in the measured data for the 3- or 4-day period at each site. For example, the plot of SSA-OBS solar radiation data shows the data for incoming radiation for all 10 pyranometers for the 4-day period, yielding 40 lines. The time of day on these plots is given in local time.


Old Aspen - Mar. 1996
Solar Radiation (W m-2)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
Time of Day


Old Black Spruce - Mar. 1996
Solar Radiation (W m-2)
0
100
200
300
400
500
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
Time of Day



10. Errors

10.1 Sources of Error

Assuming an operative instrument (each pyranometer was calibrated prior to use in the field), the sources of error include: a pyranometer that is covered by snow and the pyranometers losing their leveled orientation because of snow settling beneath the support boxes (pyranometers were releveled daily after being relocated).

10.2 Quality Assessment

10.2.1 Data Validation by Source

Data were plotted and qualitatively compared to incoming solar radiation data obtained from above the canopy at SSA-OJP and SSA-OBS. Additionally, data collected during the time the radiometers were shuffled (see Section 6.2, Field Notes) were removed.

10.2.2 Confidence Level/Accuracy Judgment

Great care was taken to level the pyranometers during installation. Quantification of the accuracy beyond the manufacturer's accuracy is difficult.

10.2.3 Measurement Error for Parameters

See Section 4.2.1.

10.2.4 Additional Quality Assessments

Visual review of plots and comparisons of instantaneous data with expected values while in the field were made.

10.2.5 Data Verification by Data Center

Data that were loaded into the data tables were spot checked against the original ASCII data that were submitted to check for data loading errors.

11. Notes

11.1 Limitations of the data

All data were collected during periods of essentially clear skies. The magnitude of solar radiation cannot be compared between the SSA-OJP and SSA-OBS or SSA-OA because SSA-OJP data were collected during early February when the solar altitude is lower than in early March when OBS and OA data were collected.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

A single measurement from one pyranometer alone cannot represent the receipt of radiation on the forest floor. The data set is intended for validation of a radiative transfer model.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

This data set can be used to understand the variability of solar radiation receipt in both coniferous and deciduous forests and could be used in validating models that predict radiation in forests.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Any spreadsheet or graphics software can be used to process these data.

14.2 Software Access

None given.

15. Data Access

The subcanopy incoming solar radiation measurement data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/ [Internet Link].

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

Contact BOREAS Information System (BORIS) staff.

16.2 Film Products

Contact BORIS staff.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Manual available from manufacturer:
Eppley Laboratory, Inc.
12 Sheffield Ave.
Newport, RI 02840
(401) 847-1020

Data logger manuals available from:
Campbell Scientific, Inc.
P.O. Box 551
Logan, UT 84321
(801) 753-2342
(801) 752-3268 (fax)

17.2 Journal Articles and Study Reports

Davis, R.E., C. Woodcock, and J.P. Hardy. 1996. Toward spatially distributed modeling of snow in the boreal forest. Eos Transactions, AGU 1995 Fall Meeting, Abstract, p. 218.

Davis, R.E., J.P. Hardy, W. Ni, C. Woodcock, J.C. McKenzie, R. Jordan, and X. Li. 1997. Variation of snow cover ablation in the boreal forest: A sensitivity study on the effects of conifer canopy. Journal of Geophysical Research. 102(D24):29,389-29,395.

Hardy, J.P., R.E. Davis, and J.C. McKenzie. 1995. Snow Distribution Around Trees: Incorporation of snow interception patterns into spatially distributed snow models. Eos Transactions, AGU 1995 Fall Meeting, Abstract, p. 202.

Hardy, J.P., R.E. Davis, and R. Jordan. 1996. Snow melt modeling in the Boreal forest. Eos Transactions, AGU 1996 Fall Meeting, Abstract, p. 196.

Hardy, J.P., R.E. Davis, R. Jordan, X. Li, C. Woodcock, W. Ni, and J.C. McKenzie. 1997. Snow ablation modeling at the stand scale in a boreal jack pine forest. Journal of Geophysical Research. 102(D24): 29,397-29,405.

Hardy, J.P., R.E. Davis, R. Jordan, W. Ni and C. Woodcock, 1998. Snow ablation modelling in a mature aspen stand of the boreal forest. Hydrological Processes, 12 (10/11), p. 1763-1778.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Ni, W., X. Li, C.E. Woodstock, J.L. Roujean, and R.E. Davis. 1997. Transmission of solar radiation in boreal conifer forests: Measurements and models. Journal of Geophysical Research. 102(D24):29,555-29,566.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

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ASCII    - American Standard Code for Information Interchange
BOREAS   - BOReal Ecosystem-Atmosphere Study
BORIS    - BOREAS Information System
CD-ROM   - Compact Disk-Read-Only Memory
CGR      - Certified by Group
CPI      - Certified by Principal Investigator
CPI-???  - CPI but questionable
CRREL    - Cold Regions Research and Engineering Laboratory
DAAC     - Distributed Active Archive Center
EOS      - Earth Observing System
EOSDIS   - EOS Data and Information System
FFC-W    - BOREAS Focused Field Campaign - Winter
FOV      - Field of View
GIS      - Geographic Information System
GMT      - Greenwich Mean Time
GSFC     - Goddard Space Flight Center
HTML     - Hyper-Text Markup Language
HYD      - Hydrology
IR       - Infrared
NAD83    - North American Datum of 1983
NASA     - National Aeronautics and Space Administration
NSA      - Northern Study Area
OA       - Old Aspen
OBS      - Old Black Spruce
OJP      - Old Jack Pine
ORNL     - Oak Ridge National Laboratory
PANP     - Prince Albert National Park
PIR      - Precision Infrared Radiometer
PRE      - Preliminary
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RH - relative humidity
SRC - Saskatchewan Research Council
SSA - Southern Study Area
temp - Temperature
TF - Tower Flux
URL - Uniform Resource Locator

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Davis, R.E., J. P. Hardy, W. Ni, C. Woodcock, C.J. McKenzie, R. Jordan and X. Li, 1997. Variation of snow cover ablation in the boreal forest: A sensitivity study on the effects of conifer canopy. J. of Geophys. Res., 102 ($N_2$4), 29,389-29,396, December 26, 1997.

Hardy, J.P., R.E. Davis, R. Jordan, W. Ni and C. Woodcock, 1998. Snow ablation modelling in a mature aspen stand of the boreal forest. Hydrological Processes, 12 (10/11), p. 1763-1778.

Hardy, J.P., R.E. Davis, R. Jordan, X. Li, C. Woodcock, W. Ni and J.C. McKenzie, 1997. Snow ablation modeling at the stand scale in a boreal jack pine forest. , J. of Geophys. Res., 102 (N24), 29,397-29,406, December 26, 1997.

Ni, W., X. Li, C.E. Woodstock, J.L. Roujean, and R.E. Davis. 1997. Transmission of solar radiation in boreal conifer forests: Measurements and models. Journal of Geophysical Research. 102(D24):29555-29566.

If using data from the BOREAS CD-ROM series, also reference the data as:

R.E. Davis, "Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS HYD-3 team collected several data sets related to the hydrology of forested areas. This data set contains solar radiation measurements from several pyranometers (solar radiometers) placed on the snow surface in jack pine (1994) and black spruce and aspen forests (1996) in the BOREAS SSA. An array of radiometers was used to collect data for 3-4 consecutive days in each forest type to study the hypothesis that energy transfer and snow water equivalent would vary spatially as a function of canopy closure. The quality of the data is good, because the days were generally clear and the radiometers were checked daily to remove anything that landed on the radiometers. The data are available in tabular ASCII files.

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